A new generation of HDR display with super multi-zones mini LED

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ABSTRACT

We propose a new generation of HDR display with active matrix mini-LED backlight for LCD. The display enables super multi-zones display by using new type of backlight drive, which achieved better contrast and less halo defect. Through both instrument test and perception experiments, we evaluated the performance of HDR LCD.

1. INTRODUCTION

With the development of mobile phone technology and the improvement of display performance, the demand for High Dynamic Range (HDR) display is more and more urgent. Compared to normal LCD, HDR display can achieve both high brightness and deep dark state. It has surfaced as a candidate for future displays. Micro LEDs enable pixel dimming and are considered as the ideal backlight for HDR LCDs. However, it will take a long time to overcome the large-scale transfer of micro LED technology. Mini LED has larger chip size than micro LED, and the cost is acceptable for commercial applications, which has been considered as a good solution for LCD to achieve HDR display.

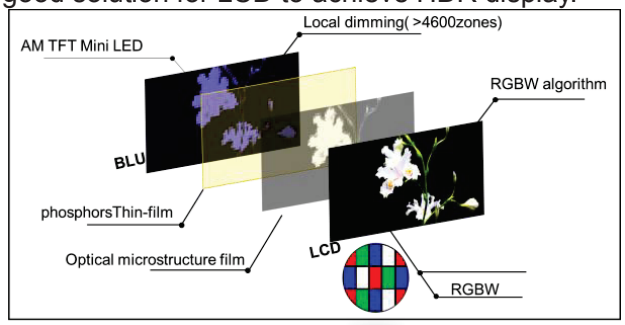


Figure 1 The structure scheme of AM TFT HDR LCD

In our previous study, we have proposed HDR mobile display with mini LED local dimming backlight [1-2]. We also propose five key points of small size HDR display, and among which the most important point is luminance resolution compared to normal LCD. In recent years, we fabricated several HDR LCDs with 288 and 512 local dimming zones, which have significant improvement in terms of peak brightness and contrast. However, these panels have some visual defects that cannot be ignored on the display. In order to alleviate these defects, we have developed a new generation of HDR LCD-Active Matrix (AM) TFT HDR. As shown in Figure 1, we use the LTPS substrate as the driving backplane of the Mini LED, which achieved super multi-zones backlight adjustment and active matrix driving. The LTPS backplane could precisely control each LED by controlling the IC signal input, so that excellent visual effect is obtained. These fabricated displays were used to compare with normal IPS LCD. The main performance of above displays is demonstrated as Table 1.

Table1. Main parameters of normal IPS LCD and HDR LCD displays

Display	Normal IPS LCD	HDR LCD	HDR LCD	AM TFT HDR LCD
Size	5.99"	6.46"	5.99"	5.99"
Resolution (pixel)	1080×2160	1440×2880	1080×2160	1080×2160
PPI	403	498	403	403
Peak Luminance (nits)	500	1000	1000	1000
Contrast Ratio	1500:1	>20,000:1	>20,000:1	>100,000:1
Color gamut	86%DCI-P3	100%DCI-P3	100%DCI-P3	100%DCI-P3
Local Dimming Zones	NA	288	512	>4600

In this paper, we analyze and compare the optical performance of different backlight partitions HDR LCDs and conducted human visual perception experiments. The relation between local dimming zones and visual effects of HDR display has been studied. And we implemented a new generation of HDR display with super multi-zones, which performance is comparable to OLED.

2. RESULT AND SIMULATION

In order to comprehensively evaluate the performance of HDR displays, we selected 8 different images, as shown in Figure 2. The optical performance test and human visual perception experiments about these pictures have been conducted to HDR displays and normal IPS LCD.

2.1 Optical performance

We have used the LMK 5 luminance / color equipment to measure the optical performance of above 4 LCD displays. The image Fig.2a has been taken as an example to analyze the difference of optical performance with different dimming zones.

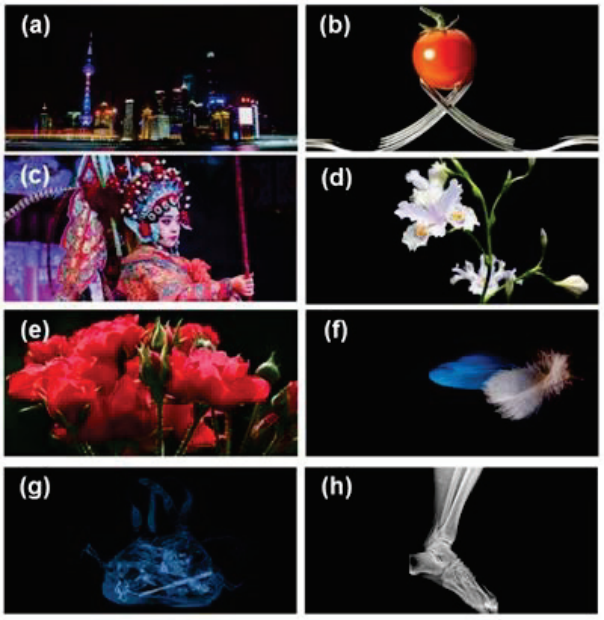
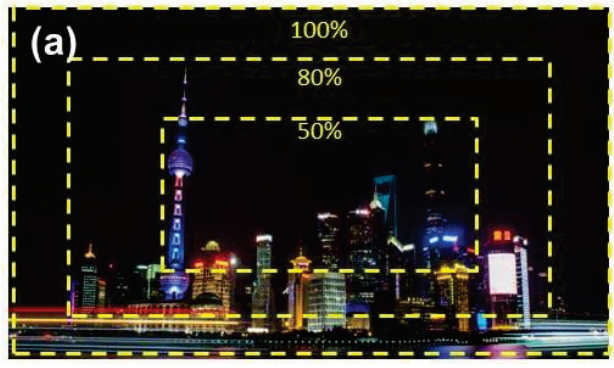


Figure 2 Images for evaluate the performance of HDR displays



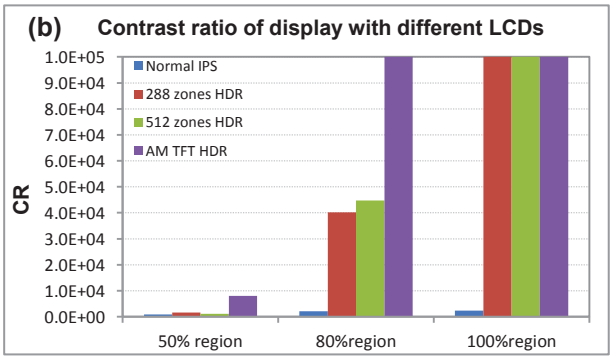
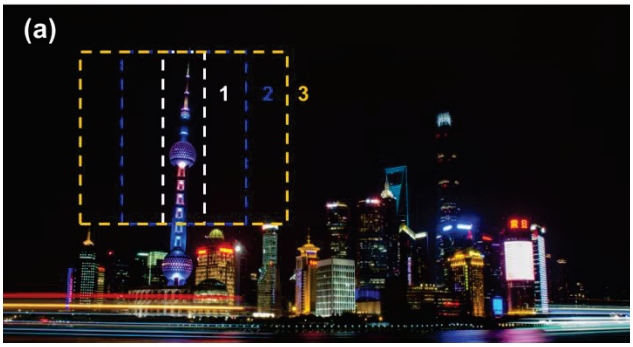


Figure 3 Contrast ratio of figure 2a with different LCDs

As shown in Fig 3, in 50% picture area, the AM TFT HDR LCD has the highest contrast 8017. However, the contrast of 288 and 512 partitions HDR LCDs are slightly higher than normal IPS LCD, about 1500. When the image area is 80%, the display with more partitions has the higher contrast. Particularly, the contrast of AM TFT HDR LCD is super high to over 100,000. In the entire picture, the contrast ratio of different partition HDR LCDs exceeds 100,000, which is much higher than normal IPS LCD's (about 1500).



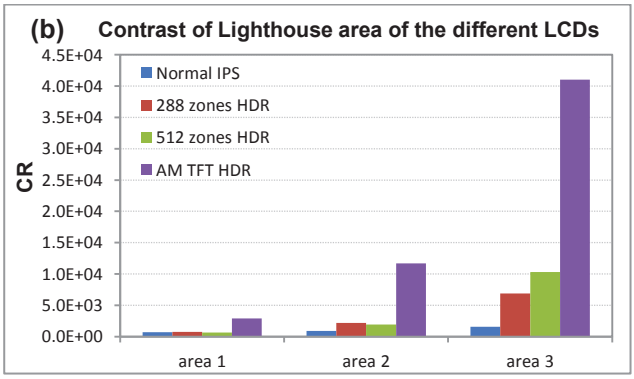


Figure 4 Contrast ratio of lighthouse area with different LCDs

To further analyze the effect of the number of backlight partitions on the optical performance of the picture display, we extracted the contrast of the lighthouse area of the different LCDs. The contrast of different areas near the lighthouse is showed in Figure 4. The AM TFT HDR LCD shows excellent contrast in the area 1, which is four times the contrast of other LCDs. In the area 3, the contrast of the 512-zones HDR LCD has reached 10,000 or more, nearly double the contrast of the 288-zones HDR LCD of 6800. These results show that the more partitions of LCD, the better performance of pictures, especially the picture with multiple levels of detail.

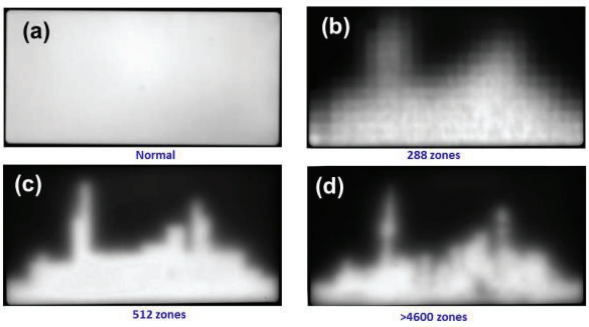
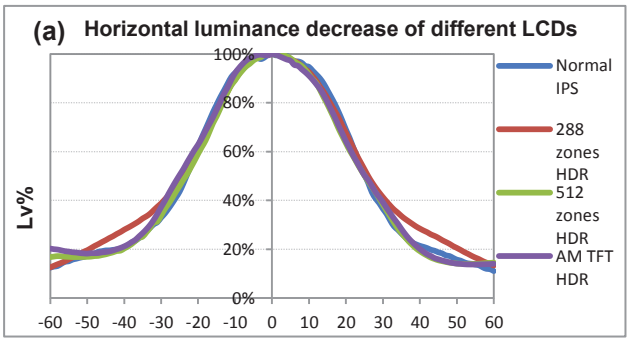


Figure 5 Luminance distribution of the backlight incident on LC layer with different LCDs: (a) Normal IPS, (b) 288 zones HDR, (c) 512 zones HDR and (d) AM TFT HDR.

Figure 5 shows luminance distribution of the backlight incident on LC layer with different local dimming zones. When the number of partitions is only 288, we can obviously observe the boundaries of different backlight partitions. These backlight boundaries are not conducive to be adjusted by the HDR picture algorithm, and will bring defects in the picture display. The backlight of the 512 partition has no obvious partition boundaries, but the backlight adjustment in the detail area is limited. The backlight partition of the AM TFT HDR LCD is more than 4600, and the partition has no obvious boundary. More importantly, it can perfectly display the difference between the brightness and the darkness of the picture detail area. As the backlight partition increases, HDR display provide better local dimming effect and higher matching with the image content. This is strongly related to the contrast of the picture. We believe that to achieve the HDR effect of different images, especially detailed images, the backlight partition should be more than 512 partitions.



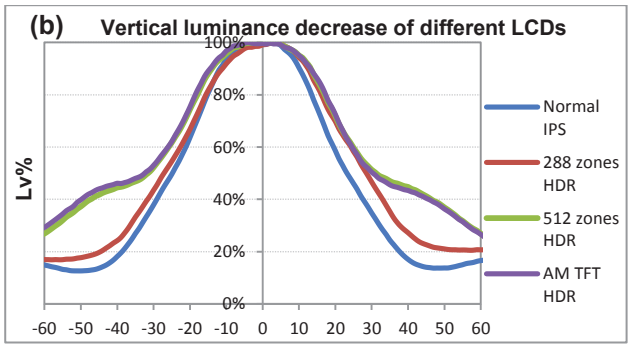


Figure 6 Luminance decrease ratio of different LCDs

Figure 6 plots the horizontal and vertical luminance decrease ratio of different LCDs. Figure 6a shows that the luminance decrease ratio of different panels in the horizontal direction is basically equivalent. However, AM TFT HDR and 512 zones HDR have a lower luminance decrease ratio than ordinary LCDs in the vertical direction, especially above 30° view angle. These results show that AM TFT HDR and 512 zones HDR have a wider view angle, which can bring better experience when playing games and watching videos.

2.2 Perception experiments

For evaluating the display performance of AM-TFT HDR LCD more realistically, we have evaluated the visual effects of these LCDs from five key parameters: contrast, peak luminance, darkness, gradation and artifacts. We identified 20 volunteers with normal vision and no color blindness as participants in visual effects evaluation. These participants are 20-35 years old (the main audience for new display technologies), with a male to female ratio close to 1:1. In the experiment, four LCD screens were placed side by side on the table. The participants evaluated the eight pictures shown in Fig.2 displayed in each panel with different viewing angles (front view and 45° side view). The merits of each parameter are set from low to high with 5 grades: very poor, unacceptable, ordinary, excellent and perfect, corresponding to 1, 2, 3, 4, and 5 respectively.

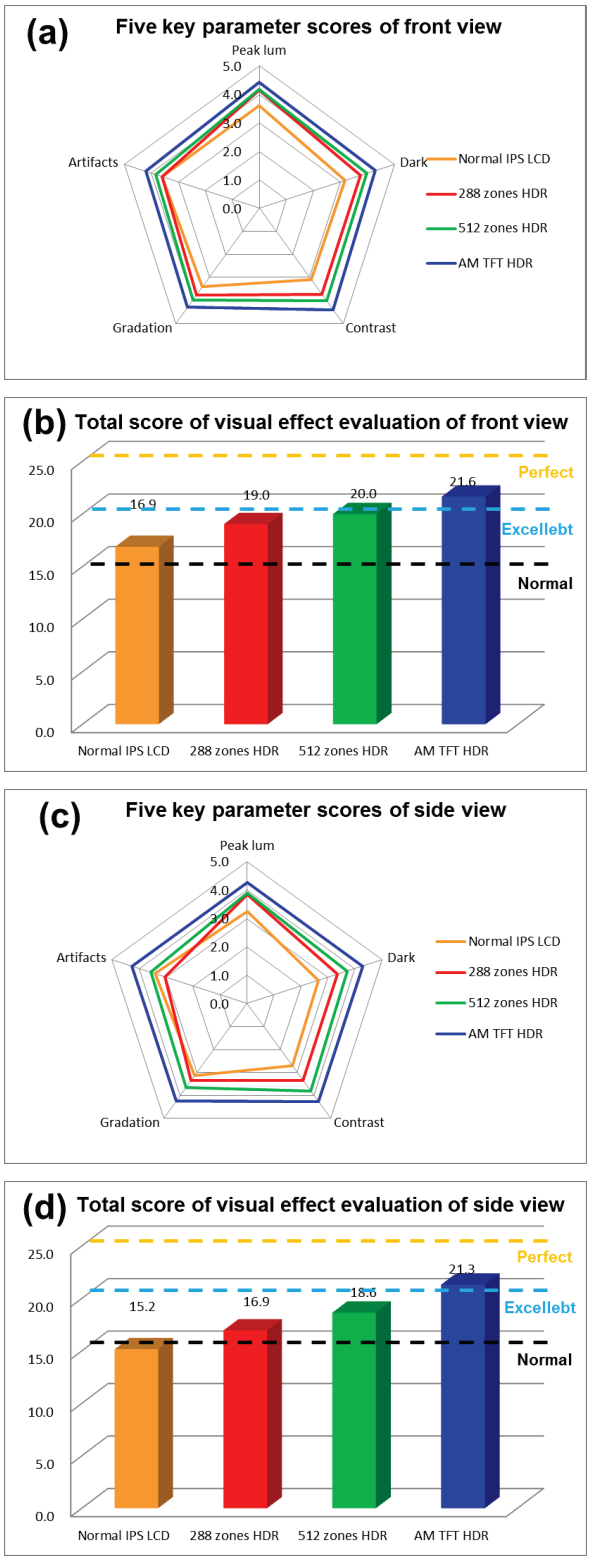


Figure 7 Perception experiment results of 8 images with different LCD displays under different viewing mode: (a) and (b) front view, (c) & (d) side view.

Figure 7 shows the visual evaluations of different LCD displays with front view and 45° side view. In both viewing angles, HDR LCDs are superior to normal IPS LCD in peak luminance, contrast and gradation. Moreover, as the number of partitions increases, these advantages become more apparent. Therefore, the increase of local dimming zones is more conducive to dark, contrast and artifacts of image.

Compared both front view and 45° side view, the total score of the visual evaluation of the 288 zones HDR LCD decreased the most. This is due to the fact that the 288 zones HDR LCD have obvious partition boundaries and the displayed defects are visible in 45° side view. Except the artifacts of which 512 zones HDR LCD is better than 288 zones HDR LCD, other image properties are basically the same. However, the 512 zones HDR LCD still has halos in the details of the picture. In order to achieve good visual effects, the number of zones for HDR LCD should be higher than 512. Active Matrix TFT HDR LCD with more than 4600 local dimming zones achieved an excellent performance: high brightness and contrast, no obvious defects even in 45° side view. It is considered comparable to OLED, and has a higher lifetime.

3. CONCLUSION

In this paper, we first developed the LTPS substrate as the Mini LED driver backplane in smartphone. The AM TFT HDR LCD with ultra-high backlight partitions of more than 4600 in 5.99 inch, which is the highest partitions currently reported about the Mini LED LCD. Through both instrument test and human visual perception experiments, we evaluated the performance of HDR LCD with different local dimming zones. This new generation of HDR display with excellent performance has great prospects in applications of automotive and video game display.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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